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INTERCOMPARISON OF PYRHELIOMETERS

By HERBERT H. KIMBALL, Meteorologist

During a recent visit of Dr. Ladislas Gorczyński, Director of the Meteorological Service of Poland, to the Central Office of the United States Weather Bureau, an opportunity was afforded to obtain interesting comparisons between several different types of pyrheliometers,[1] the results of which are given in Table 1.

TABLE 1.—*Comparison of Marvin Silver Disk pyrheliometer, with Moll and Weather Bureau thermoelectric recording pyrheliometers, June 7, 1924*

Solar time	Marvin No. 3 (gr.-cal.)	Thermoelectric pyrheliometers			Ratio, columns 2/4	Ratio, columns 2/5
		Moll		Weather Bureau scale		
		Scale	Millivolts			
(1)	(2)	(3)	(4)	(5)	(6)	(7)
0:28	1.198	5.19	20.76	* 17.5	0.0576	3.37
0:32	1.184	5.13	20.52	17.2	578	3.35
1:03	1.214	5.31	21.24	18.2	573	3.43
1:07	1.216	5.32	21.28	18.2	571	3.43
1:11	1.204	5.27	21.08	18.0	570	3.42
1:15	1.186	5.20	20.80	17.8	570	3.42
1:19	1.197	5.20	20.80	18.05	575	3.47
1:23	1.182	5.17	20.68	18.0	571	3.48
1:27	1.169	5.13	20.52	17.65	570	3.44
1:31	1.165	5.13	20.52	17.6	568	3.43
1:35	1.172	5.11	20.44	17.85	574	3.49
1:39	1.168	5.09	20.36	18.8	573	3.50
1:43	1.157	5.04	20.16	17.6	573	3.49
Mean ratio					0.0572	3.44

Ångström pyrheliometer No. 105, which was in use at Mount Weather, Va., from 1907 to 1911, and Smithsonian Silver Disk No. 1, were also included in the above comparison. Dr. Gorczyński read Ångström No. 105, and the Smithsonian instrument was read by myself. The Ångström readings were in almost exact agreement with the readings of Marvin No. 3. The Smithsonian instrument, unfortunately, had recently been returned from field work, and the screws that clamp the silver disk during shipment had not been loosened. In consequence, the Smithsonian instrument read low.

Since the departure of Doctor Gorczyński the following comparisons have been obtained between Marvin No. 3 and Smithsonian No. 1.

TABLE 2.—*Comparisons between Marvin Silver Disk Pyrheliometer No. 3 and Smithsonian Silver Disk No. 1*

Date	Smithsonian No, 1	Marvin No. 3	Ratio, $\frac{\text{Marvin}}{\text{Smithsonian}}$
	Gr. cal.	*Gr. cal.*	
June 20	1.030	1.006	0.977
June 25	1.172	1.140	0.973
June 26	1.294	1.267	0.979
June 26	1.318	1.281	0.972
Mean ratio			0.975

Through comparison of the Moll thermoelectric pyrheliometer with an Ångström pyrheliometer reserved by him as a substandard instrument Doctor Gorczyński had previously obtained the factor 0.057 to reduce millivolts recorded by the Moll instrument to gram-calories. Therefore, the comparisons of Table 1 confirm the accuracy of this factor.

From Table 2 it appears that the Marvin pyrheliometer in June, 1924, was reading 2.5 per cent lower than Smithsonian No. 1. Previous comparisons had shown that Ångström No. 105 read 2.4 per cent lower than Smithsonian No. 1. Therefore, as the result of the above comparisons, we conclude that the Moll instrument is still in accord with the Ångström standard, but reads 2.5 per cent lower than the Smithsonian pyrheliometric scale.[2]

It is important to correlate the readings of this Moll instrument with the Smithsonian pyrheliometric scale, since it has been loaned by Doctor Gorczyński to Mr. Andrew Thompson, Director of the Samoan Magnetic and Meteorological Observatory, for use at that island station.

[1] Published descriptions of these several instruments will be found as follows: Ångström pyrheliometer: Astrophysical Jr., 9: 332–335; Smithsonian Silver Disk pyrheliometer: Annals of the Astrophysical Observatory of the Smithsonian Institution, 3: 47–52; Marvin Silver Disk pyrheliometer: MONTHLY WEATHER REVIEW, 1919, 47, 769. Weather Bureau thermoelectric pyrheliometer: MONTHLY WEATHER REVIEW, 1923, 51: 239–242 Moll thermoelectric pyrheliometer, MONTHLY WEATHER REVIEW, 1924, 52: 299–301.

[2] Smithsonian pyrheliometry revised. Smithsonian Misc. Coll. Vol. 60, No. 18 1913.

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INVESTIGATIONS RELATIVE TO THE POLAR FRONT[3]

By J. W. SANDSTRÖM

In connection with the earlier investigations[4] an attempt was made to apply the theory of "cyclone families" in practical weather service work. This test proved especially fruitful of results since the theory contains a very simple and clearly formulated law as to the paths of cyclones. The result of the test was followed with lively expectation.

The theory of cyclone families states, as is well known, that successive cyclones appear in families, so to speak, and with the succeeding depression having its path somewhat to the south of that of the preceding one, until finally the cyclones move tangent to the tropical belt of high pressure. The first members of the family appear in high latitudes and run more and more to the south until they come so far south that cyclonic formation becomes no longer possible. The theory is a consequence of the polar front conception. A cyclone draws the cold polar air behind it and brings the polar front to the south of its own center, and since the succeeding cyclone follows the polar front it must move more to the south. The process is shown by J. Bjerknes and H. Solberg in Figure 12 of their work, "Life Cycle of Cyclones and the Polar Front Theory of Atmospheric Circulation."[5]

The application of the theory in practical weather service is, then, simple enough. From the known path of a cyclone that has just passed, one draws the path of the succeeding cyclone somewhat more to the south and thereby obtains within relatively narrow limits the path which the next depression will take. Only when the path runs in the vicinity of the tropical "high" is there

[3] Translated from *Meteorologische Zeitschrift, Band 41, Heft 2* (February, 1924) by W. W. Reed.

[4] *Meteorologische Zeitschrift, Band 40, Heft 9* (September, 1923).

[5] *Geofysiske Publikationer, Vol. III, Nr. 1*, 1922.

no succeeding more southerly cyclone to be expected, but attention must be turned to the north, where a new cyclone family is already active. These new cyclonic paths will behave in the same way as did those of the earlier family. Although in this process, as in all other meteorological phenomena, there are exhibited all kinds of irregularities, it is clear that a law concerning cyclonic paths stated so precisely must be very valuable in practical weather service work, since certainty in weather prediction always depends essentially on correct judgment as to the path of an approaching cyclone.

On the basis of this law I sought to draw in advance the paths of coming cyclones. However, it soon appeared that they did not follow the paths thus drawn, but took paths altogether different. After several attempts were made with poor success, I then had carried out at my institute a detailed investigation on the basis of Hoffmeyer's charts, which were very well adapted to the purpose. At first two statistical methods were employed. If the law is correct, it must happen that the path of the succeeding cyclone lies much more often to the south than to the north of that of the earlier cyclone. The tabulation showed, however, no noteworthy difference. Further, in case the law is correct the north-south distance between two successive cyclonic paths must be far greater when the path of a depression lies to the north than when it is situated to the south of the path previously charted. Here, also, the measurements gave no differences worth mentioning.

In this investigation a large number of Hoffmeyer's charts were used. They were considered according to months as is shown in Figures 1 and 2 (not reproduced). On these charts the dots show the positions of the cyclone, the number below a dot giving the day of the month on which the center was situated at that point and the connecting lines indicating the cyclonic path.

If these charts are examined closely, it is found, even without statistical treatment, that the paths of the successive cyclones do not have, as a rule, the same form as that found for preceding disturbances and that often later paths intersect earlier ones in all kinds of ways. In the cases in which they do run parallel it happens that the succeeding path lies a little to the north just as often as it lies a little to the south. On the whole, no confirmation of the law of cyclone families can be gathered from these charts.

I recommend that every meteorologist who is interested in the practical application of the ingenious exposition by Bjerknes—and all who are engaged in weather forecasting should be interested—proceed further with this elaboration of the Hoffmeyer charts; it is easily done and is productive of results. I believe that they, with me, will gradually arrive at the convictions (1) that cyclone families in the Bjerknes sense do not exist, (2) that the behavior of cyclones is not regulated by a polar front, and (3) that the discontinuity, which is called the polar front, appears, in general, only with the cyclones and is a result of their activity.

Meteorological processes depend to a large degree on the distribution of land and water and on the topography of the land. A theory that omits these important elements and takes into consideration only the influence of latitude must necessarily be incomplete. This circumstance is probably the main reason for the lack of success that appears in the practical application of the Bjerknes theory.

I do not mean to say by this that such abstractions should be avoided. On the contrary, by such an abstract treatment of a certain single influence, the consequences of the same follow far more clearly and simply than when it is considered together with other influences. Care should be taken not to accept the partial and qualified results obtained in this way as a general and exclusive basis for practical work.

If I use here the method employed by Bjerknes, it is not only to obtain a direct comparison with his results, but also because I find this method better than all others. However, my results may not be used as a foundation in weather service work until the decisive influences of topography and distribution of land and sea are taken into consideration.

When the temperature data from the European yearbooks issued before the war are entered on synoptic charts, the horizontal temperature gradient can be measured with great accuracy. Even in non-cyclonic weather there are then found numerous small, abrupt changes in temperature distribution, which can hardly be explained otherwise than by slightly marked discontinuities. In general the lines of discontinuity run with the isotherms and appear to have their cause in the movement of the air relative to the isotherms. Such discontinuities are to be expected in the area between the regions of polar and tropical air; in this area the horizontal temperature gradient and the movement relative to the isothermal lines are considerable. As a matter of fact, this can be demonstrated on the Hoffmeyer charts despite the small number of temperature stations. If the influence of land and sea is excluded and latitude alone is taken into consideration, then in non-cyclonic weather these lines of discontinuity will run with the parallels as represented in Figure 3 (not reproduced). According to my view this wide zone of discontinuities should be substituted for the Bjerknes polar front.

In this view the cyclones are produced by differences in velocity of the air currents relative to each other somewhat in the same manner as rotating water whirls in rivers and other currents.

According to the above investigation relative to cyclone families, the successive cyclones have little or no connection among themselves. As the result of different specific gravities and considerable differences in velocity of the air currents relative to each other, there are developed, as a rule, marked discontinuities according to the Bjerknes scheme. Figure 4 (not reproduced) shows these lines of marked discontinuity and in addition the manner in which the lines of Figure 3, indicating less abrupt discontinuity, have been distorted by the cyclone.

In Sweden the defects of the Bjerknes theory stand forth prominently in those cases where the distribution of land and water is especially influential on the weather; such is often the case in our land (Norway). Among the cyclones that are very deceptive on account of this distribution are those that form over the Baltic Sea or stagnate there and bring the well-known three-day rains over eastern Sweden. These cyclones are not formed according to the Bjerknes scheme or have lost that structure if once they possessed it. If, in despite of this, predictions are made according to the Bjerknes scheme, they will in general prove erroneous.

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[The paper concludes with a discussion of charts showing the weather in Sweden for June 18–19, 1921. In this there is pointed out the failure of the prediction according to the Bjerknes plan, and the statement is made that it would have been far better to have applied an old empirical rule which would have prognosticated the weather correctly.—Ed.]